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TESTS FOR SALINITY AND SODIUM STATUS OF SOIL AND OF IRRIGATION WATER

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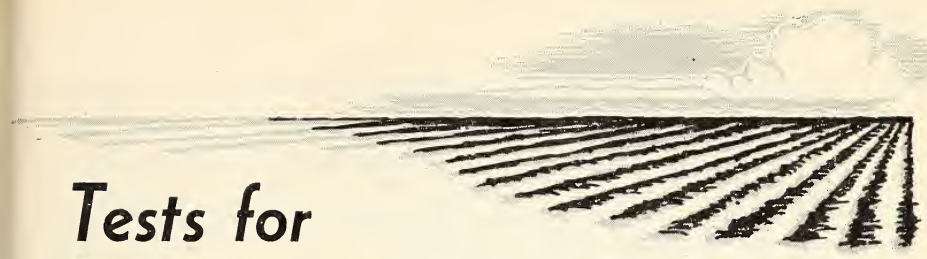

Tests for Salinity and Sodium Status of Soil and of Irrigation Water[1]

By L. A. Richards, *principal soil physicist*, C. A. Bower, *senior chemist*, and Milton Fireman,[2] *senior soil scientist, Soil and Water Conservation Research Branch, Agricultural Research Service*

THIS CIRCULAR gives tests for estimating the agricultural significance of soluble salt and exchangeable sodium in soil and the quality of irrigation water. The tests are intended primarily for professional agricultural workers and are designed to give a maximum of information for a minimum of effort. Soils and waters will be encountered, therefore, for which the information obtained by the tests will be inadequate or indecisive. For example, the exchangeable sodium test is indecisive for soils with extremely high salinity and also for soils with extremely low salinity and high sodium. In these cases determinations such as those given in United States Department of Agriculture Handbook 60[3] should be employed. The Handbook gives standard measuring procedures along with background information.

Sampling

The significance of a measurement depends on whether the sample tested is representative of the condition being diagnosed or appraised. As much skill and experience are required for sampling, compositing, and subsampling as are required for making determinations and interpreting the results. This applies both for soil and water samples.

Soil salinity is especially critical during seed germination, and in this case soil to a depth of 2 or 3 inches should be tested. Otherwise, samples that are representative of the major root zone should be tested. This will depend on the kind of crop to be grown and the

[1] This work was carried out by the United States Department of Agriculture in cooperation with the 17 Western States and the Territory of Hawaii.

[2] Resigned.

[3] United States Salinity Laboratory Staff. diagnosis and improvement of saline and alkali soils. U. S. Dept. Agr. Handb. 60, 160 pp., illus. 1954.

soil profile. Seasonal and management factors may need to be considered during sampling.

The roots of some row crops tend to concentrate under the irrigation furrow where the soil may be nonsaline. In this case a salinity measurement of the surface crust of soil at the top of the row might give a very high reading but could be misleading as to the effect of the salts on the crop. Compositing samples from several locations will make a soil test more representative of an area. If much sampling is to be done, a sampling tube will be helpful. Inexpensive soil sampling tubes are available commercially.

The soil sample to be tested should be air-dried and pulverized. The sample may be passed through a screen with 1- to 2-mm. openings, before or after drying. Rocks and plant materials can be discarded. Mixing the sample by rolling and pulling on a sheet of paper will aid in taking a representative subsample for making the soil paste and especially for filling the soil measuring cups. The more finely a soil is pulverized, the easier it is to take a representative subsample for chemical tests.

Care must be exercised to make sure that irrigation water samples are representative and are protected from contamination. The quality of water from an irrigation well may change markedly with time after starting the pump. Also, the quality of water in a natural stream will vary with volume of flow and location of the sampling point with respect to tributaries.

Basis for Tests

Soluble salts adversely affect the productivity of soils in two principal ways: (1) By increasing the salinity of the soil solution and (2) by increasing the content of exchangeable (adsorbed) sodium. The latter occurs when the ratio of sodium salts to calcium-plus-magnesium salts is relatively high and produces in most soils an unfavorable physical condition along with various direct and indirect detrimental effects on plant growth. Excess salinity of the soil solution can be corrected by leaching with water of good quality; whereas, the removal of excess exchangeable sodium requires, in addition, the application of an amendment such as gypsum, providing this mineral is not already present in the soil.

A measurement of the electrical conductivity of the solution extracted from a saturated soil paste provides a good index of soil salinity for agricultural purposes. This measurement takes the field-moisture range of the soil into account and gives a salinity index that is directly related to the concentration of the soil solution in the field.

The concentration of sodium in the saturation extract can be approximated by subtracting the concentration of calcium-plus-magnesium from the total cation concentration as estimated from the conductivity.

For each soil there is a close relation between the contents of sodium and calcium-plus-magnesium in the soil solution and the relative proportions of these ions that are present in the exchangeable form. The relation is sufficiently similar for most soils to be useful for estimating exchangeable-sodium status, and a test is given for dividing

soils into four classes, depending on the intensity of the exchangeable-sodium problem.

If the tests indicate that excess exchangeable sodium may be a problem, it is desirable to estimate the amount of soluble calcium that should be added to replace the exchangeable sodium during reclamation. The soluble calcium required in the replacement process, which is referred to as the soluble-calcium-requirement, can then be used to estimate the rate of application of chemical amendment that is necessary for reclamation. For this purpose, a test is given in which the soil is treated with a calcium solution, and the amount of calcium which reacts with the soil is determined.[4]

When the application of a chemical amendment is indicated and it is desired to use acid-forming materials such as sulfur or sulfuric acid, a test should be made to determine if alkaline-earth carbonates (lime) are present.

A test for gypsum in soil is included. This will be useful only under special conditions, as when forecasting the effect of using a high sodium water for irrigation of soil that initially contains little exchangeable sodium.

In judging the quality of waters for irrigation, primary consideration is ordinarily given to the salinity and sodium hazards involved. The electrical conductivity of water is a good index of the salinity hazard, while the sodium hazard is largely determined by the proportion of sodium to calcium-plus-magnesium present, together with the total salt content as indicated by electrical conductivity. Under some conditions, the bicarbonate content as related to the content of calcium-plus-magnesium may influence the sodium hazard. It should also be recognized that waters may contain toxic amounts of boron. The tests for water quality given here are based only on the electrical conductivity and the content of calcium-plus-magnesium, the sodium being estimated. For more detailed information on water quality, publications such as United States Department of Agriculture Handbook 60 should be consulted.

Use of Equipment

The equipment and supplies for these tests are listed in the Appendix. The composition and directions for the preparation of the reagents are also given in the Appendix. Usual chemical precautions should be observed in cleaning the funnels and glassware. Evaporation deposits should be avoided on dispensing surfaces with which the standard solutions come in contact.

The following suggestions may be of assistance in the use of the equipment.

Electrical-Conductivity Set

Any electrical-conductivity set having satisfactory operating characteristics may be used. The dial should be calibrated in millimhos per centimeter with means for converting values to the reference temperature of 25° C. The accuracy should be better than 10 per-

[4] This test is a modification of the gypsum requirement test proposed by W. R. Schoonover, "Examination of Soils for Alkali." University of California Extension Service, Berkeley, Calif. 1952. (Mimeographed.)

cent, and it should be possible to rinse the conductivity cell and take a reading with solution volumes as low as 2 or 3 ml. Follow the manufacturer's directions for the use and maintenance of the set.

Some conductivity sets have twin cells for comparing a test solution with a saturated gypsum solution. If this type is used, rinse and fill both cells with saturated gypsum solution. The calibrated dial of the bridge should then read 2.2 millimhos/cm. The temperature correction is automatically taken into account in this case if the gypsum comparison cell has the same temperature as the measuring cell.

After use, the cells should be rinsed and left full of distilled water.

Vacuum Filter

This is a portable unit consisting of a vacuum jar with a rubber stopper to hold the filter funnels and a hand-operated vacuum pump making use of a rubber bulb. The bulb used for the vacuum pump remains collapsed when the filter unit is working properly. The rubber at the seals around the vacuum jar and at the funnel stem should be kept clean and may need to be moistened during use, especially as the rubber ages. If the valves start to leak, they may be disassembled and scrubbed out with water or the valves can be readily replaced. A glass vial is used inside the vacuum jar to receive the filtrate.

Soil Funnel

This is a special funnel for extracting solution from a soil paste. The paste is supported by a flat disk of filter paper, and a grooved pattern under the paper conducts the extract to the central stem of the funnel and into the vacuum chamber.

Turbid extracts containing suspended particles cause negligible interference in the determination of electrical conductivity, but these particles may interfere with the test for calcium-plus-magnesium. Extracts may be clarified by allowing time for particles to settle out or by the following precautions. Start the extraction with the vial in a nonreceiving position, i. e., displaced toward the rubber bulb. Then move the vial into the receiving position by tilting the filter after the extract has visibly cleared. Since the volume of extract available from coarse soils is limited, the following alternate procedure for avoiding turbidity can be used. Add saturated paste first to the center of the paper in the soil funnel. After the paper is visibly wetted to the outer edge, operate the vacuum bulb just enough to seat the paper. Then finish adding the soil paste and apply full vacuum.

The extraction time is related to leaching rates in the field. If the soils encountered are mostly slow to extract, a large soil funnel using 15-cm. paper may be preferable.

Displace the soil cake from the funnel by blowing on the stem. The funnel can be prepared for immediate reuse by rinsing with water and drying with tissue paper. The final step in the drying operation is to blow water from the stem while absorbing the water with tissue inside the funnel.

Glass Funnel

Vacuum filtration of a suspension may be accomplished as follows. Assemble the vacuum filter with a 50-mm. glass funnel and with a

vial inside the vacuum jar. Use 11-cm. retentive filter paper with a 90° symmetrical fold. Some care will be required to minimize air leaks along the folds. Press the dry, folded paper firmly down into the funnel and hold in place while pouring in the soil suspension. Allow a few seconds for the paper to wet and soften. Rest the palm of the left hand lightly on the top edge of filter paper and apply the vacuum by repeated compressions of the bulb. After collecting the first few milliliters of filtrate, the seal between the paper and funnel can be improved by pinching the adjacent fold with the tip of the first finger, the thumb being outside the funnel, and by pressing against the opposite fold of the filter paper with the tip of the second finger.

Automatic Pipet

Support the pipet in the palm of the hand at an angle of approximately 45° during use. Adjust the rubber bulb up or down, so that when the bulb is collapsed its expansion will draw in just a drop or two more than is necessary to fill the pipet. When so adjusted, the pipet can be used several times before it is necessary to empty the overflow. This is done by compressing the bulb with the pipet horizontal and with the overflow tip pointed down. Before delivering 1 ml. of solution for test, thoroughly rinse the pipet once or twice with a partial loading of the test solution.

Hand Buret

The hand buret is made from a 5-ml. graduated pipet, rubber tubing, and a glass bead. For adjusting the fill to the zero mark and for titrating, the buret is held vertically in the left hand, palm down, between the first and second fingers, while the outflow is controlled by pinching the bead between the thumb and first finger. The right hand is thus free to swirl the vial containing the test solution. The buret can be mounted in a clamp if desired. It is helfpul to illuminate the titration vessel with a local light source. Complete the titration slowly, because several seconds are required for the titration reaction to go to completion.

Soil-Sample Measuring Cups

Brass cups are provided for measuring out approximately 2½-gm. and 5-gm. samples of dry pulverized soil. Mix the soil by stirring in its container or by pulling on a flexible sheet. Fill the measuring cup heaping full by dipping into the soil. Use the spatula to strike the soil off level with the cup. During the strike-off process, the soil should be packed gently into the cup. The sample of soil to be tested can be weighed if desired.

Soil Salinity

Saturated Soil Paste

Place a representative sample of the soil to be tested in a paper cup and stir with a spatula while adding distilled water. The amount of sample should be sufficient to fill the soil funnel. The soil and water mixture is consolidated from time to time during the wetting process

by tapping the container on the work bench. At saturation the soil paste glistens as it reflects light, flows slightly when the container is tipped, and slides freely and cleanly off the spatula for all soils except those with high clay content.

New operators may wish to make the following check. Cover the cup and allow the paste to stand for several hours. If free water collects on the surface, the water content is too high. If the paste stiffens and loses its glisten, the water content is too low. The saturated pastes of some soils, especially woody peats, tend to stiffen after standing, and an overnight wetting time for such soils can be used.

Solution Extraction

Assemble the vacuum filter, placing a filter paper in the soil funnel and a vial in the vacuum chamber. Transfer the soil paste to the funnel with the spatula and tap the assembled filter on the bench to exclude air bubbles. Tilt the filter assembly so that the vial is in the nonreceiving position, i. e., displaced toward the rubber bulb. Develop the vacuum by alternately compressing and releasing the rubber bulb. After the filtrate becomes clear, as determined by inspection, move the vial to the receiving position under the funnel by tilting the filter assembly. Continue the filtration until sufficient solution is obtained.

Electrical-Conductivity Measurement

Empty the conductivity cell, rinse twice with a partial loading, and fill the cell with the sample of the saturation extract to be tested, following the manufacturer's instructions for balancing the bridge and converting the reading to the reference temperature of 25° C.

Interpretation of the Electrical-Conductivity Measurement

The following scale relates the conductivity to soil salinity and to crop growth.

	Soil salinity			
Salinity effects mostly negligible.	Low	Medium	High	Very high
	Yields of very sensitive crops may be restricted.	Yields of many crops restricted.	Only tolerant crops yield satisfactorily.	Only very tolerant crops yield satisfactorily.

0 2 4 8 16

Electrical conductivity of the saturation extract (millimhos per centimeter at 25° C.).

If the electrical conductivity reading is high, the need for leaching is indicated. Excess soluble salts in soil can be removed only by the action of water moving downward through the soil profile. Whether amendments should be used during leaching will depend on the sodium status of the soil.

Sometimes a trend toward salt accumulation during farming operations can be reversed by minor changes in the method of irrigation

and the amount of irrigation water applied. In other cases ponding of water on the soil surface for long periods may be required. Adequate drainage should be provided in any case.

Exchangeable-Sodium Status of Soil

Calcium-Plus-Magnesium in Saturation Extract

Pipet into a vial 1 ml. of the *clear* saturation extract obtained for the conductivity test. Dilute to a volume of about 5 ml. with distilled water. Add 1 or 2 crystals of *DDC reagent,* swirl to dissolve, and then add one small plastic measuring cup of the *buffer-indicator reagent.* When the *buffer-indicator reagent* has dissolved, the color of the solution should be wine red. Add *EDTA reagent* from the 5-ml. buret a drop at a time until the color of the solution changes to blue or green. Record the milliliters of *EDTA reagent* consumed. This value is a measure of the calcium-plus-magnesium concentration in the saturation extract.

Interpretation of Tests for Indicating Sodium Status

Locate the point in figure 1 corresponding to the measured values for the electrical conductivity and the volume of 0.01 N *EDTA reagent* consumed in titrating 1 ml. of the saturation extract. The vertical lines separate the soil salinity classes shown at the top of the figure. The curves separate areas that represent different levels of exchangeable sodium. If the experimental point lies in the area marked "No Exchangeable Sodium Problem," no further tests for sodium need ordinarily be made. If the experimental point lies in one of the higher sodium areas, the test for the soluble-calcium-requirement should be made to indicate the amount of amendment needed for reclamation.

Both plant tolerance and soil physical condition were considered in determining the limits for the sodium classes shown in figure 1, and field crops growing in medium-textured soils were given primary consideration. When diagnosing sodium problems, full advantage should be taken of local information and experience. If the rate of water movement in the field soil is satisfactory, then the decision on the use of amendments will depend mainly on the tolerance of the crop to exchangeable sodium. For example, satisfactory yields of beets or barley might be obtained in peat soil at "medium sodium" or even "high sodium" levels. On the other hand, sodium-sensitive crops like stone fruits and avocado may show strong sodium injury at sodium levels included in the lowest sodium class of figure 1.

Soluble-Calcium-Requirement

Add 100 ml. of *calcium reagent* to the mixing bottle. Then add one large measuring cup (5 gm.) of soil, stopper, and shake vigorously for 1 minute. Let stand for 5 minutes or longer and determine whether the soil is flocculated. Flocculation is indicated if a relatively clear layer of liquid forms at the top of the suspension. Lack of flocculation is evidence that the soil contains a high amount of exchangeable sodium and that insufficient *calcium reagent* has been added. In this case, discard the contents of the mixing bottle and

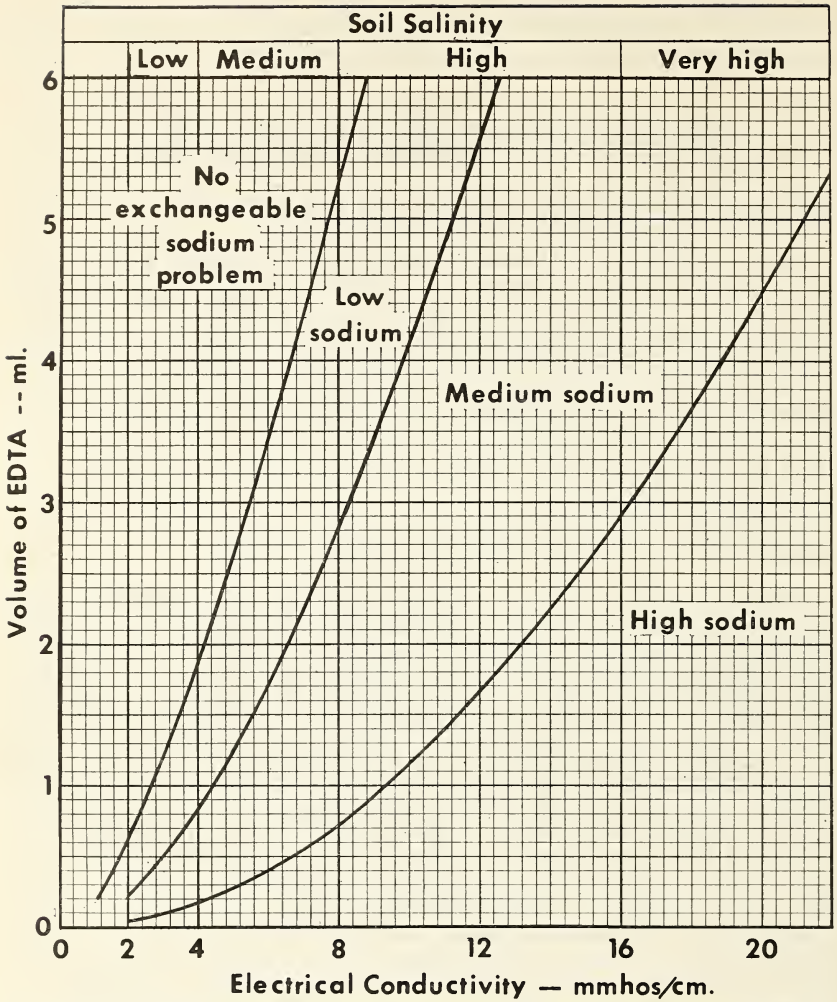

FIGURE 1.—Diagram for distinguishing 4 salinity classes and 4 sodium-status classes for soil. The point in the diagram representing the sample is determined by the measured values of the conductivity and the volume of 0.01 N *EDTA reagent* required to titrate 1 ml. of saturation extract.

restart the test, using the same amount of *calcium reagent* but a small measuring cup (2½ gm.) of soil. If a relatively clear layer of liquid does not form when the small scoop is employed, the soil probably contains an unusually high amount of exchangeable sodium and should be studied in greater detail by standard methods.

Assemble the vacuum filter with the glass funnel and a vial in the vacuum jar. Use 11-cm. retentive paper. Shake the soil suspension for an additional ½ minute, and collect 10 or 15 ml. of filtrate in the receiving vial. Transfer 5 ml. of the extract to a clean vial, using the 5-ml. pipet. Add 1 or 2 crystals of *DDC reagent*, swirl to dissolve, and then add 1 small plastic measuring cup of *buffer-indicator reagent*. Add *EDTA reagent* from the 5-ml. buret a drop at a time until the

color of the solution changes from wine red to blue or green. Record the milliliters of *EDTA reagent* consumed. In a similar manner determine the milliliters of *EDTA reagent* consumed by 5 ml. of *calcium reagent.* Subtract the milliliters of *EDTA reagent* consumed by the 5 ml. of soil extract from the amount consumed by 5 ml. of the *calcium reagent.* Multiply this difference by 4, if a large measuring cup of soil was used, or by 8, if a small cup of soil is used. The product is the soluble-calcium-requirement value.

For soil samples in the conductivity and titration ranges covered by figure 1, negative values for the soluble-calcium-requirement are possible and indicate that the soil contains gypsum. If the soluble-calcium-requirement is found to be greater than 10, using a large measuring cup of soil, a more reliable value for the soluble-calcium-requirement will be obtained by repeating this test using a small measuring cup of soil.

Alkaline-Earth Carbonates (Lime)

Transfer one large measuring cup of soil to a vial and moisten to saturation with distilled water. Add 2 or 3 drops of hydrochloric acid and note whether effervescence (fizzing) occurs. Effervescence indicates that alkaline-earth carbonates are present.

Interpretation of the Soluble-Calcium-Requirement Value

The soluble-calcium-requirement indicates the excess of exchangeable sodium over any native gypsum that may be present in the soil and therefore is related to the amount of amendment required for reclamation.

Table 1 gives suggested rates of application of commonly used amendments to soils having various soluble-calcium-requirement values. The rates are based on the amount of amendment required to replace the excess exchangeable sodium in a 1-foot depth of soil. Because a small amount of exchangeable sodium in soil is not objectionable, no application of amendment is ordinarily required unless the soluble-calcium-requirement exceeds 2.

Gypsum is a suitable amendment for all soils having an appreciable soluble-calcium-requirement. The choice of amendment should be made on the basis of cost, except that sulfur and sulfuric acid, particularly if large amounts are needed, should be applied only to soils containing alkaline-earth carbonates.

TABLE 1.—*Suggested rate of application of amendments as related to the soluble-calcium-requirement*

Soluble-calcium-requirement value	Amendment needed per acre foot of soil		
	Sulfur	Sulfuric acid	Gypsum
	Tons	*Tons*	*Tons*
4	0. 64	2	3. 5
6	1. 3	4	7
10	2. 6	8	14

Gypsum Content of Soil

Place 25 ml. of distilled water and 1 large measuring cup (5 gm.) of soil in the shaking bottle, stopper, and shake vigorously for 2 minutes continuously or for shorter intermittent periods over a longer time interval. Assemble the vacuum filter with the glass funnel. Use 11-cm. filter paper and collect more than 5 ml. of filtrate in a vial inside the vacuum chamber.

Transfer 5 ml. of the filtrate to a clean vial, using the 5-ml. transfer pipet. Slight turbidity of the filtrate will not interfere with this test. Add approximately 5 ml. of acetone, shake, and allow several minutes for gypsum to precipitate. Wash the glass funnel, dry with tissue paper, and install a new filter paper. Filter the water-acetone solution containing gypsum crystals and, when through, wash the vial and the precipitate on the filter paper with 5 ml. or more of acetone.

Flatten the filter paper on a work sheet of smooth paper, gypsum up. Fold inward 2 opposite edges to give a folded width of about one-third of the diameter, and cut into 1-cm strips across the folds. Assemble the folded pieces and place in a vial. Add any gypsum flakes remaining on the worksheet, and also add exactly 10 ml. of distilled water to this vial. Use the 5-ml. transfer pipet. Stopper, shake for 1 minute, and read the electrical conductivity of the resulting gypsum solution. Follow the manufacturer's instructions for balancing the bridge and converting the electrical conductivity to the reference temperature of 25° C. Use the curve in figure 2 to estimate the gypsum content of the soil.

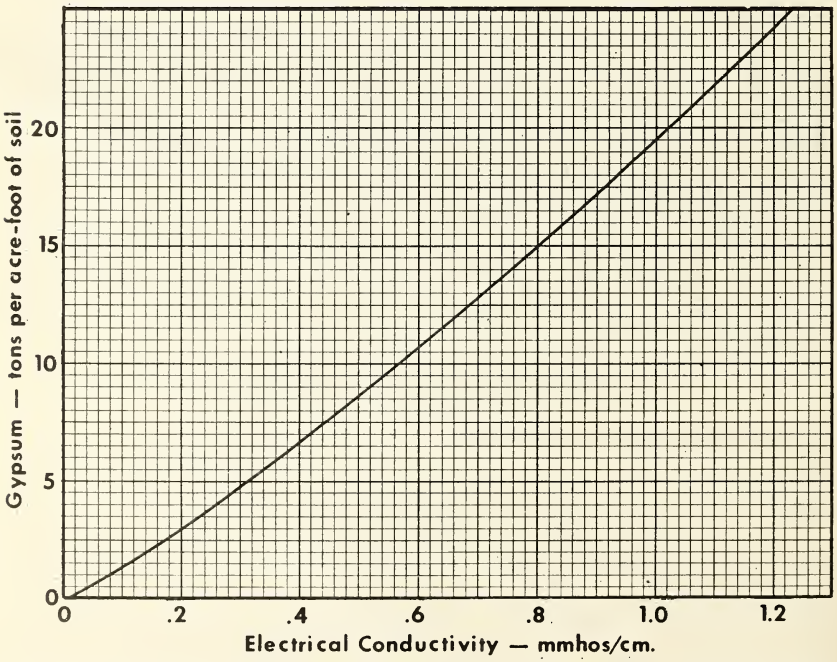

FIGURE 2.—Gypsum content of soil as related to the electrical conductivity of the test solution.

A form such as the one shown in the Appendix is useful for reporting the results of the soil tests and their interpretation.

Quality of Irrigation Water

Electrical-Conductivity Measurement

Empty the conductivity cell, rinse twice, and fill the cell with the water to be tested. Follow the manufacturer's instructions for balancing the bridge and converting the electrical conductivity to the standard reference temperature of 25° C.

Calcium-Plus-Magnesium Content

Pipet 5 ml. of the irrigation water into a vial. Add 1 or 2 crystals of *DDC reagent*, swirl to dissolve, and then add 1 small plastic measuring cup of *buffer-indicator reagent*. When the *buffer-indicator reagent* has dissolved, the color of the solution should be wine red. Add *EDTA reagent* from the 5-ml. buret a drop at a time until the color changes to blue or green. Record the milliliters of *EDTA reagent* consumed.

Interpretation of Water Tests

The diagram in figure 3 may be used to classify irrigation water with respect to salinity and sodium hazard. Locate the point on the diagram corresponding to the electrical conductivity and the milliliters of *EDTA reagent* consumed by 5 ml. of the water.

Vertical lines in the figure at conductivity values of 0.25, 0.75, and 2.25 millimhos per cm. divide irrigation waters into 4 salinity-hazard classes, which are designated at the top of the figure as C1, low; C2, medium; C3, high; and C4, very high conductivity.

The diagonal curves in the figure separate waters into 4 classes on the basis of sodium hazard: S1, low; S2, medium; S3, high; and S4, very high.

The following statements apply to the salinity and sodium-hazard classes:

Low salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Medium salinity water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

High salinity water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

Very high salinity water (C4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

Low sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium.

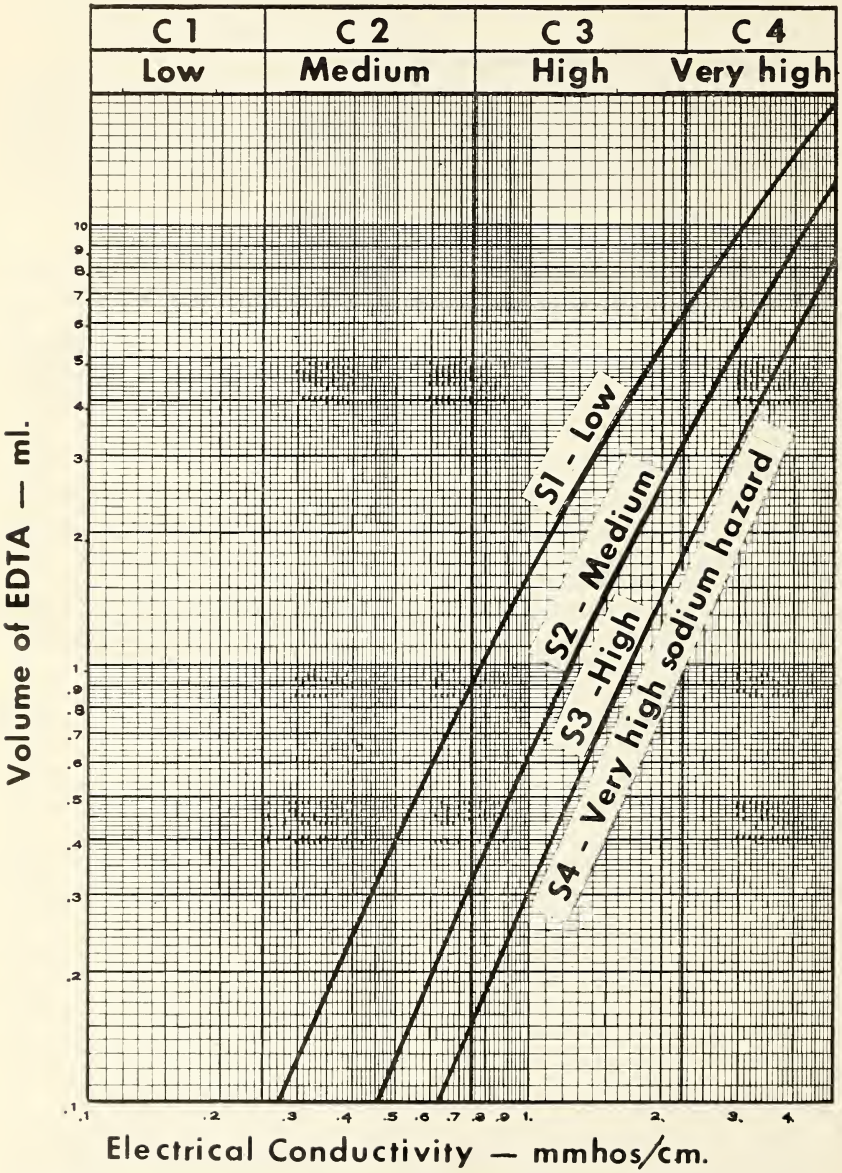

Figure 3.—Diagram for distinguishing 4 conductivity classes and 4 sodium-hazard classes of irrigation water. The point in the diagram representing the sample is determined by the measured values of the conductivity and the volume of 0.01 N *EDTA reagent* required to titrate 5 ml. of the water.

Medium sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

High sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management—good drainage, high leaching, and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

Very high sodium water (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

Further information on the quality of irrigation water is given in United States Department of Agriculture Circular 969.[5]

A form such as the one shown for water tests in the Appendix may be used for reporting water quality.

[5] Wilcox, L. V. classification and use of irrigation waters. U. S. Dept. Agr. Cir. 969, 19 pp., illus. 1955.

Appendix

Forms

The following forms are suggested for reporting soil and water tests.

SOIL TESTS

Sample No. 6 Collected by: Marvin Brown Date collected: May 9, '55

Description: John Jones Farm; alfalfa field; composite sample from 0-12" layer

Salinity

Electrical conductivity of saturation extract: 9.2 millimhos/cm. at 25° C.

Interpretation: Land needs leaching; only salt-tolerant crops will yield satisfactorily.

Sodium Status

EDTA reagent consumed by 1 ml. of saturation extract: 1.5 ml.

Interpretation (from fig. 1): Medium sodium problem

Soluble-Calcium-Requirement

EDTA reagent consumed by 5 ml. of Ca reagent: 5 ml.
EDTA reagent consumed by 5 ml. of soil extract: 4 ml.
Difference: 1 ml.

Soluble-calcium-requirement: Large soil cup (difference x 4) [✓]
Small soil cup (difference x 8) [ ] 4

Alkaline-earth carbonates: Not present [✓] present [ ]

Interpretation: An amendment should be applied; as alkaline carbonates are not present the amendment should be gypsum; suggested rate — 3.5 tons per acre.

Gypsum Content

Electrical conductivity of test solution: ____ millimhos/cm. at 25° C.

Gypsum content (from fig. 2): ____ tons/acre

Interpretation: _____

WATER TESTS

Sample No. 2 Collected by: Marvin Brown Date collected: May 9, '55

Description: John Jones farm; west well; discharge rate — 4,000 gal. per min.

Conductivity

Electrical Conductivity: 0.6 millimhos/cm. at 25° C.

Interpretation (from fig. 3): C2 medium salinity water; will require moderate amount of leaching. Moderately salt-tolerant crops can be grown.

Sodium

EDTA reagent consumed by 5 ml. of water: 0.30 ml.

Interpretation (from fig. 3): S2 medium sodium water; will present appreciable sodium hazard in fine-textured soils under low leaching unless gypsum is present.

Portable Set for Salinity and Sodium Tests

Item No.	Name and procedure	Size or quantity	Description	Number required
1	Portable battery-operated electrical conductivity bridge and cells. (As described in Soil Sci. 80: 55 (1955), or equivalent.)			1.
2	Portable vacuum filter assembly. (As described in Soil Sci. 79: 423 (1955), or equivalent.)			1.
3	Soil filter funnel	100 ml	Uses 5.5-cm. filter paper	1.
4	Filter paper	5.5 cm	Retentive; hard (S and S No. 576, or equivalent).	100 in box.
[1] 5	Soil filter funnel	550 ml	Uses 15-cm. paper	1.
[1] 6	Filter paper	15 cm	Retentive; hard (S and S No. 576, or equivalent).	
7	Vials	50 x 25 mm	Glass	6 to 10.
8	Paper cups	6 or 8 oz		As needed.
9	Spatula	6 in		1.
10	Automatic pipet	1 ml	With rubber bulb	1.
11	Serological pipet. Make into a buret by cutting off the tip, which is then rejoined by a piece of rubber tubing containing a glass bead.	5 ml	1/10-ml. divisions	1.
12	Transfer pipet	5 ml		1.
13	*DDC reagent*—Sodium diethyldithiocarbamate crystals	½-oz. bottle		
14	*Buffer-indicator reagent*—Weigh 10.6 gm. Na_2CO_3, 8.4 gm. $NaHCO_3$, 7.6 gm. disodium magnesium ethylenediaminetetraacetate, and 0.01 gm. Eriochrome black T into a mortar. Grind to pass a 60-mesh sieve and mix thoroughly. The amount of Eriochrome black T will depend on the purity. The above directions apply for the product supplied by Pharmaceutical Laboratories, Aniline Division, Allied Chemical & Dye Corp.	1-oz. bottle		1.
15	Plastic cup for measuring out 50 mg. of *buffer-indicator reagent.* Make from clear plastic rod, ¼ in. in diameter x 7/16 in. long. Drill 3/16-in. axial hole, 3/16 in. deep. Attach a wire handle by a press fit in a cross hole at the other end of the plastic part.			1.

16	*EDTA reagent*—Dissolve 2.0 gm. disodium dihydrogen ethylenediaminetetraacetate in 900 ml. of water. Standardize against 0.01 N $CaCl_2$ (as described in USDA Handbook 60) and adjust to a normality of exactly 0.01 by diluting with the required amount of water.	250 ml	0.01 N	1.
17	Saturated gypsum solution—This item is for conductivity sets using a reference cell containing saturated gypsum solution. Put reagent grade calcium sulfate crystals to a depth of about 1 cm. in the 250-ml. dispenser bottle, add distilled water, and shake vigorously for 1 minute. With a large excess of fine crystals, shaking vigorously for 1 minute will give a saturated solution. A brief settling time before use is adequate because suspended crystals do not interfere with the conductivity comparison. Replace water or crystals as needed.	250 ml		1.
18	Distilled water. (Polyethelyene dispensing bottles are convenient for items 16, 17, and 18. The dispensing tubes can be closed with a cap made from Neoprene tubing and glass rod.)	500 ml		1.
19	Hydrochloric acid—Approximately 3 N; 1 part concentrated hydrochloric acid in 3 parts water.	2 oz	Dropper bottle	1.
20	Tissue paper		Absorbent, for drying glassware.	

[1] Needed only for unusually fine-textured soils of low permeability.

Additional Equipment for Soluble-Calcium-Requirement and Gypsum Tests

Item No.	Name and procedure	Size or quantity	Description	Number required
21	Glass filter funnel—Pad the stem of the funnel with plastic tubing ¼ in. in diameter x 1/16-in. wall x 1½ in. long.	50 mm	Short stem, fluted. Uses 11-cm. filter paper.	1.
22	Filter paper	11 cm	Retentive; hard (S and S No. 576, or equivalent).	100 in box.
23	Shaking bottle	4 oz	Screw cap	1.
24	Graduated cylinder	100 ml		1.
25	Soil cups for measuring out 5-gm. and 2.5-gm. samples of dry, pulverized soil. Cups with polished cylindrical cavities machined from brass bar stock. Solder each cup to the ends of a U-shaped handle bent from a 1/16-in. brass rod 12 in. long.	Cup for 5-gm. sample.	4.16 ml. capacity, 0.686 in. inside diameter, 0.686 in. deep.	
		Cup for 2.5-gm. sample.	2.08 ml. capacity, 0.686 in. inside diameter, 0.343 in. deep.	
26	*Calcium reagent*—Approximately 10 meq./l., standardized. Obtain saturated calcium sulfate solution as directed in item 17, except use a larger mixing bottle and wait longer for solid particles to settle. Decant clear solution and add 2 volumes of distilled water to 1 volume of solution. It is convenient to use the *calcium reagent* from a 1,000-ml. polyethylene bottle. Keep the closure free from evaporation deposits. The volume of 0.01 N *EDTA reagent* to titrate 5 ml. of the *calcium reagent* is determined by the same titration procedure used for irrigation water. This titration volume should be redetermined from time to time.	1,000 ml	Calcium sulfate solution.	
27	Acetone	500 ml	Technical grade	1.

Technical Notes

Figure 1 is based on data given in United States Department of Agriculture Handbook 60, pp. 25–27, which relates the sodium-adsorption-ratio ($Na/\sqrt{(Ca+Mg)/2}$) of saturation extracts of soils to exchangeable-sodium-percentage. The curves in the figure represent constant sodium-adsorption-ratios of 8.4, 17.7, and 46, which correspond, respectively, to exchangeable-sodium-percentages of 10, 20, and 40. The volumes of *EDTA reagent* in milliliters, given on the vertical side of the figure, when multipled by 10 are equivalent to calcium-plus-magnesium concentrations of saturation extracts in milliequivalents per liter. The sodium concentration of the saturation extract is considered to be the difference between the total cation concentration as indicated by electrical conductivity and the calcium-plus-magnesium concentration. The figure on page 12 of Handbook 60 was employed to relate electrical conductivity to total cation concentration.

Soluble-calcium-requirement values correspond approximately to milliequivalents of exchangeable sodium minus milliequivalents of gypsum per 100 grams of soil.

Figure3 is essentially equivalent to the diagram for the classification of irrigation waters given on page 80 of Handbook 60. Following the same procedure that was used in connection with figure 1, the sodium-adsorption-ratio is estimated from electrical conductivity and calcium-plus-magnesium concentration. The volume of *EDTA reagent* in milliliters, given on the vertical scale of figure 3, when multiplied by 2 is equivalent to calcium-plus-magnesium concentrations in milliequivalents per liter. The figure on page 70 of Handbook 60 was employed to relate the electrical conductivity to the total cation concentration of waters.

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